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TITLE: DETECTION OF SIGHT LINE AND APPARATUS THEREFOR

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Abstract Text - FPAR (2):

SOLUTION: The sight line positions are respectively determined by both of a pupil center method computation section 2D and cornea reflection method computation section 2E for the eyeball images of an operator M captured by an optical image pickup apparatus 1. When a detected result difference decision section 2F makes decision that the difference of the two detected LOS positions is not confined within a preset prescribed range continuously for the specified time, recomputation to determine the sight line positions again is carried out by the pupil center method computation section 2D according to the moving quantity of the head determined by a head moving quantity calculation section 2G. As a result, the exact detection by the algorithm of the pupil center method is always carried out and, therefore, the exact sight line positions may be detected at all times without being affected by the rotating angle of the eyeballs and the mounting positions of illumination light for image pickup.

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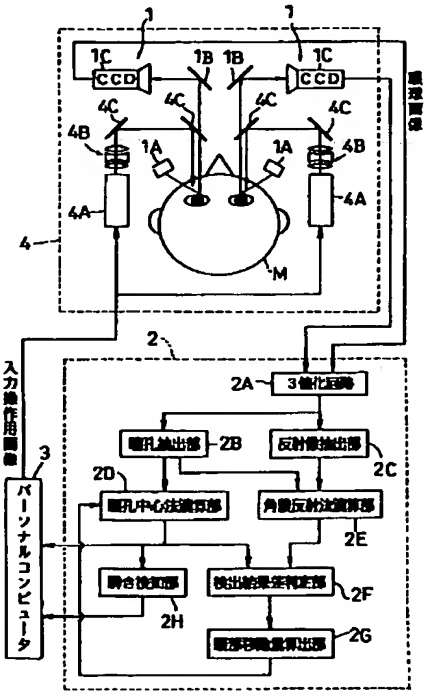
(54)【発明の名称】　視線検出方法及びその装置

(57)【要約】
【課題】　検出対象の眼球の正確な視線位置が常に検出できるようにする。
【解決手段】　光学式撮像機器１で取り込んだオペレータＭの眼球画像に対して瞳孔中心法演算部２Ｄおよび角膜反射法演算部２Ｅの両方でそれぞれ視線位置を求めると共に、検出した二つの視線位置の差が予め設定した所定範囲内に一定時間継続して納まっていないと検出結果差判定部２Ｆが判定した場合、頭部移動量算出部２Ｇで求められた頭部の移動量に応じて瞳孔中心法演算部２Ｄで視線位置を求め直す再演算を行う。これにより瞳孔中心法のアルゴリズムによる的確な検出は常に行われるので、眼球の回転角や撮像用照明光の取り付け位置に左右されることなく正確な視線位置が常に検出できる。



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【特許請求の範囲】

【請求項1】　光学式撮像手段により撮影された眼球画像に基づいて眼球の視線位置を検出する視線検出方法において、同一眼球画像に対して瞳孔中心法のアルゴリズムと瞳孔－角膜反射法のアルゴリズムの両アルゴリズムそれぞれによって視線検出結果を得る演算過程と、両アルゴリズムによる検出結果の差が予め設定した所定範囲内に納まっているか否かを判定する検出結果差判定過程と、検出結果差判定過程の判定結果が否であれば、瞳孔－角膜反射法のアルゴリズムの検出結果に基づき検出対象の眼球のある頭部の動きに起因する誤差が除去された瞳孔中心法のアルゴリズムによる検出結果を求め直すための再演算を行う検出結果再演算過程とを備えていることを特徴とする視線検出方法。

【請求項2】　光学式撮像手段により撮影された眼球画像に基づいて眼球の視線位置の検出を行うよう構成された視線検出装置において、眼球画像から瞳孔中心法のアルゴリズムに従って視線検出結果を得る瞳孔中心法演算手段と、眼球画像から瞳孔－角膜反射法のアルゴリズムに従って視線検出結果を得る角膜反射法演算手段と、前記両演算手段による検出結果の差が予め設定した所定範囲内に納まっているか否かを判定する検出結果差判定手段と、検出結果差判定手段の判定結果が否であれば、角膜反射法演算手段の検出結果に基づき検出対象の眼球のある頭部の動きに起因する誤差が除去された瞳孔中心法演算手段による検出結果を求め直すための再演算を行う検出結果再演算手段とを備えていることを特徴とする視線検出装置。

【請求項3】　請求項2に記載の視線検出装置において、視線位置の検出結果が、コンピュータの入力操作用として利用されるよう構成されている視線検出装置。

【請求項4】　請求項3に記載の視線検出装置において、コンピュータからの指令に従って少なくとも入力操作用画面を表示するヘッドマウントディスプレイの前記入力操作用画面に眼球の視線が向けられるよう構成されている視線検出装置。

【発明の詳細な説明】

【0001】

【発明の属する技術分野】この発明は、光学式撮像手段を用いて取り込んだ眼球画像に基づいて眼球の視線位置（視線方向）を検出する方法および装置に係り、特に検出対象の眼球の正確な視線位置が常に検出されるようにするための技術に関する。

【0002】

【従来の技術】普通、眼球の視線位置を検出する方法としては、瞳孔中心法と瞳孔－角膜反射法が特に有用とされている。瞳孔中心法は、視線位置の変化による眼球の回転に応じて瞳孔中心が移動することを利用しており、瞳孔の中心位置を測定して単純に視線位置を求出する手法である。瞳孔－角膜反射法は、角膜表面の光反射で生

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じる虚像（反射像）が視線位置の変化による眼球の回転に応じて移動することを利用しており、角膜表面の虚像の中心位置と瞳孔中心位置を測定して両位置の関係から視線位置を求出する手法である。

【0003】実際に視線位置を求出するに際しては、検出対象の眼球を光学式撮像手段によって撮影して眼球画像を取り込んでおき、瞳孔中心法あるいは瞳孔－角膜反射法のアルゴリズムに従って取り込んだ眼球画像を解析することにより視線位置が決定される。

【0004】瞳孔中心法の場合、視線位置の変化に伴う瞳孔中心位置の移動量が大きいので、視線位置が検出し易いという利点がある。瞳孔－角膜反射法の場合、眼球の回転による瞳孔中心位置の移動と、頭部の動きによる瞳孔中心位置の移動とをある程度分離することができるので、頭部が完全に固定されていなくても視線位置が検出できるという利点がある。

【0005】

【発明が解決しようとする課題】しかしながら、上記の瞳孔中心法による検出方法でも、瞳孔－角膜反射法による検出方法でも、検出対象の眼球の正確な視線位置が常に検出できるわけではないという問題がある。

【0006】すなわち、瞳孔中心法による検出方法の場合、検出はし易くても、眼球の回転による瞳孔中心位置の移動と頭部の動きによる瞳孔中心位置の移動とが分離できないので、頭部の動きがあると、これが誤差となって視線位置を正確に検出することが出来ないという問題がある。

【0007】また瞳孔－角膜反射法による検出方法の場合、眼球の回転角や撮像用照明光の取り付け位置によっては、角膜表面に虚像が形成されず、視線位置が検出できないという問題がある。

【0008】この発明は、上記の事情に鑑み、検出対象の眼球の正確な視線位置が常に検出できる視線検出方法及びその装置を提供することを課題とする。

【0009】

【課題を解決するための手段】前記課題を解決するために、請求項1の発明に係る視線検出方法は、光学式撮像手段により撮影された眼球画像に基づいて眼球の視線位置を検出する視線検出方法において、同一眼球画像に対して瞳孔中心法のアルゴリズムと瞳孔－角膜反射法のアルゴリズムの両アルゴリズムそれぞれによって視線検出結果を得る演算過程と、両アルゴリズムによる検出結果の差が予め設定した所定範囲内に納まっているか否かを判定する検出結果差判定過程と、検出結果差判定過程の判定結果が否であれば、瞳孔－角膜反射法のアルゴリズムの検出結果に基づき検出対象の眼球のある頭部の動きに起因する誤差が除去された瞳孔中心法のアルゴリズムによる検出結果を求め直すための再演算を行う検出結果再演算過程とを備えていることを特徴とするものである。

【0010】さらに、請求項2の発明に係る視線検出装置は、光学式撮像手段により撮影された眼球画像に基づいて眼球の視線位置の検出を行うよう構成された視線検出装置において、眼球画像から瞳孔中心法のアルゴリズムに従って視線検出結果を得る瞳孔中心法演算手段と、眼球画像から瞳孔－角膜反射法のアルゴリズムに従って視線検出結果を得る角膜反射法演算手段と、前記両演算手段による検出結果の差が予め設定した所定範囲内に納まっているか否かを判定する検出結果差判定手段と、検出結果差判定手段の判定結果が否であれば、角膜反射法演算手段の検出結果に基づき検出対象の眼球のある頭部の動きに起因する誤差が除去された瞳孔中心法演算手段による検出結果を求め直すための再演算を行う検出結果再演算手段とを備えていることを特徴とするものである。

【0011】また、請求項3の発明は、請求項2に記載の視線検出装置において、視線位置の検出結果が、コンピュータの入力操作用として利用されるよう構成されていることを特徴とするものである。

【0012】また、請求項4の発明は、請求項3に記載の視線検出装置において、コンピュータからの指令に従って少なくとも入力操作用画面を表示するヘッドマウントディスプレイの前記入力操作用画面に眼球の視線が向けられるよう構成されていることを特徴とするものである。

【0013】〔作用〕次に、この発明に係る視線検出装置における作用を説明する。この発明の方法により眼球の視線位置（視線方向）を検出する場合、まず光学式撮像手段により検出対象である眼球の眼球画像を撮影して取り込んでから、次に取り込んだ眼球画像に対して瞳孔中心法のアルゴリズムと瞳孔－角膜反射法のアルゴリズムの両アルゴリズムそれぞれによる演算で二つの視線検出結果を得た後、得られた二つの検出結果の差が予め設定した所定範囲内に納まっているか否かを判定する。両アルゴリズムの検出結果の差が所定範囲内に納まっていない場合（否定の場合）、検出対象の眼球のある頭部の動きによる瞳孔中心位置の移動によって、瞳孔中心法のアルゴリズムによる検出結果に誤差が生じていることになる。

【0014】そこで、この発明の方法においては、判定結果が否定であれば、瞳孔－角膜反射法のアルゴリズムの検出結果に基づき再演算が行われて検出対象の眼球のある頭部の動きに起因する誤差が除かれた瞳孔中心法のアルゴリズムによる検出結果が求め直され、正確な視線位置が求出される。つまり、瞳孔－角膜反射法のアルゴリズムの場合、眼球の回転による瞳孔中心位置の移動と検出対象の眼球の付いている頭部の動きによる瞳孔中心位置の移動とを分離することができるので、頭部の動きによる瞳孔中心位置の移動量を求めて、これを用いて瞳孔中心法のアルゴリズムにおける瞳孔中心位置を補正することにより頭部の動きに起因する誤差を取り除くのである。

【0015】なお、両アルゴリズムの検出結果の差が所定範囲内に納まっている場合（肯定の場合）は、瞳孔中心法と瞳孔－角膜反射法の両アルゴリズムによる視線位置の検出結果は、いずれも正確ということになる。

【0016】したがって、この発明の視線検出方法においては、瞳孔中心法のアルゴリズムによる的確な検出結果が常に得られるので、眼球の回転角や撮像用照明光の取り付け位置に左右されることもなく、眼球の正確な視線位置が常に検出できることになる。

【0017】さらに、請求項2の発明の装置の場合、請求項1の発明を実施することにより、検出対象の眼球の視線位置を常に正確に検出することができる。

【0018】また、請求項3の視線検出装置の場合、常に正確に検出される視線位置に従って、コンピュータの入力操作がいつも間違いなく実行される。

【0019】また、請求項4の視線検出装置の場合、コンピュータからの指令に従ってヘッドマウントディスプレイに表示される入力操作用画面に向けられた（コンピュータ・オペレータの）眼球の視線でもって、表示中の入力操作用画面からコンピュータ操作のための入力が行われる。

【0020】

【発明の実施の形態】続いて、この発明の一実施例を図面を参照しながら説明する。図1は請求項2～4の視線検出装置の一例を用いたコンピュータコミュニケーションシステムの全体構成を示すブロック図である。また、図1のシステム中に配設されている視線検出装置は、請求項1の視線検出方法の一例を実施することにより視線位置（視線方向）を検出する装置である。

【0021】実施例のコンピュータコミュニケーションシステムは、オペレータMの眼球画像を撮影する光学式撮像機器1と、光学式撮像機器1により撮影されたオペレータMの眼球画像に基づいて眼球の視線位置を検出するよう構成さた視線検出装置2と、視線検出装置2による視線位置の検出結果に従って入力操作がなされるパーソナルコンピュータ3と、パーソナルコンピュータ3からの指令に従って少なくとも入力操作用画面が表示されるヘッドマウントディスプレイ（HMD）4とを備えており、ヘッドマウントディスプレイ4の入力操作用画面に向けられたオペレータMの眼球の視線位置が視線検出装置2により検出されるとともに、検出された視線位置に従ってパーソナルコンピュータ3に対して入力操作がなされてオペレータMとコンピュータ3の間でコミュニケーションが行われる構成となっている。

【0022】以下、実施例のコンピュータコミュニケーションシステムの各部の構成を具体的に説明する。

【0023】光学式撮像機器1はヘッドマウントディスプレイ4に設置されている赤外光源1Aとハーフミラー

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１ＢおよびＣＣＤカメラ１Ｃとからなり、赤外光源１Ａの照射光で照らされたオペレータＭの眼球がハーフミラー１Ｂを介してＣＣＤカメラ１Ｃで撮影されるとともに、撮影された眼球画像はＣＣＤカメラ１Ｃから視線検出装置２へ送出される構成となっている。なお、光学式撮像機器１は左右両眼用に一対設けられている。

【００２４】ヘッドマウントディスプレイ４は、装着するオペレータＭに入力操作用画面を提供するＬＣＤ（液晶表示装置）４Ａと、表示用光学系４Ｂおよび一対のハーフミラー４Ｃが左右両眼用にそれぞれ設けられた公知のものであり、ＬＣＤ４Ａにはパーソナルコンピュータ３から画像信号が提供され、装着するオペレータＭの眼前に入力操作用画面が拡大表示される。入力操作用画面には操作キーやアイコン等の像が所定の位置に映し出される。ヘッドマウントディスプレイ４による拡大表示の場合、視野角が拡大して、注視点の移動時におけるオペレータの視線の移動量が大きくなるので、視線位置の検出精度が向上する利点がある。

【００２５】視線検出装置２は、取り込んだ眼球画像を予め設定した「しきい値」に従って３値化処理して３値化画像を得る３値化回路２Ａと、３値化画像から瞳孔中心位置を求出する瞳孔抽出部２Ｂと、３値化画像から角膜表面に生じる反射像（虚像）の（中心）位置を求出する反射像抽出部２Ｃとを備えており、新たに眼球画像が一つ取り込まれると、瞳孔中心位置と反射像の位置が直ちに求出される構成となっている。なお、３値化画像においては、最も暗い領域が瞳像で、最も明るい領域が反射像に対応する。

【００２６】さらに、視線検出装置２は、眼球画像から瞳孔中心法のアルゴリズムに従って視線位置を求出する瞳孔中心法演算部２Ｄと、眼球画像から瞳孔－角膜反射法のアルゴリズムに従って視線位置を求出する角膜反射法演算部２Ｅとを備えている。つまり、瞳孔中心法演算部２Ｄは瞳孔抽出部２Ｂにより求められた瞳孔中心位置から比較的単純に視線位置を算出し、角膜反射法演算部２Ｅは瞳孔抽出部２Ｂにより求められた瞳孔中心位置と反射像抽出部２Ｃにより求められた反射像の位置とから視線位置を算出するのである。

【００２７】これら両演算部２Ｄ，２Ｅにより算出された視線位置は、ヘッドマウントディスプレイ４において表示される入力操作用画面に対応するものである。すなわち、予め入力操作用画面の標準点に対して視線位置のキャリブレーションが行われて、両演算部２Ｄ，２Ｅにより算出された視線位置が入力操作用画面上の注視点に対応付けられる構成となっているのである。

【００２８】具体的には、図２に示すように、入力操作用画面ＰＡの位置が既知である上下左右の４つの標準点Ｐａ～Ｐｄを順に眼球が注視して視線が各標準点Ｐａ～Ｐｄそれぞれにある時の眼球画像上での瞳孔中心位置を求めた後、さらに入力操作用画面ＰＡにおける４つの標準点Ｐａ～Ｐｄの座標とその瞳孔中心位置および瞳孔中心位置と反射像位置との相関関係を予め求めておき、この相関関係に従って実測時の瞳孔中心位置を入力操作用画面の上で対応する視線位置に変換するのである。なお、実施例の入力操作用画面の場合、左上を原点とするＸＹ直交座標で視線位置を示す構成になっている。

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【００２９】そして、視線検出装置２は、両アルゴリズムの検出結果の差が予め設定した所定範囲内に一定時間継続して納まっているか否かを判定する検出結果差判定部２Ｆを備えている。検出結果差判定部２Ｆによる判定結果が否定の（所定範囲内に納まっていない）場合、瞳孔中心法演算部２Ｄにより算出した視線位置には、オペレータＭの頭部の動きに起因する誤差が含まれていて、検出結果が正確でないことになる。

【００３０】反対に、検出結果差判定部２Ｆによる判定結果が肯定の（所定範囲内に納まっている）場合、オペレータＭの頭部に動きはなく、両演算部２Ｄ，２Ｅにより算出した視線位置には、オペレータＭの頭部の動きに起因する誤差が含まれておらず、検出結果は正確であることになる。この場合、瞳孔中心法演算部２Ｄにより算出された視線位置がパーソナルコンピュータ３へ直ちに送出される。

【００３１】さらに、視線検出装置２は、角膜反射法演算部２Ｅによる検出結果からオペレータＭの頭部の移動量を算出する頭部移動量算出部２Ｇを備えている。つまり、瞳孔－角膜反射法の場合、眼球の回転による瞳孔中心位置の移動と頭部の動きによる瞳孔中心位置の移動とを概ね分離することができるので、検出結果差判定部２Ｆによる判定結果が否定の場合、頭部移動量算出部２Ｇは、角膜反射法演算部２Ｅによる検出結果を逆変換処理するようなかたちで頭部の動きによる瞳孔中心位置の（眼球画像上での）移動量（Δｘ，Δｙ）を算出して瞳孔中心法演算部２Ｄへ送り込む構成となっているのである。

【００３２】瞳孔中心法演算部２Ｄの場合、より具体的には、図３に示すように、眼球画像ＰＢの上での瞳孔中心位置Ｐｓ＝（ｘｃ，ｙｃ）である場合、次の演算式（１）に従って、図２に示すように、入力操作用画面ＰＡにおける視線位置Ｐｔ＝（Ｘｗ，Ｙｗ）が算出される。演算式（１）のＡＢＣＤを要素とするマトリックスは、入力操作用画面ＰＡにおける４つの標準点Ｐａ～Ｐｄに基づいて前述のようにして求められる眼球画像ＰＢの上での瞳孔中心位置Ｐｓと入力操作用画面ＰＡの上での視線位置Ｐｔとの間の相関関係（対応関係）に該当する。

【００３３】

【数１】

$$\begin{bmatrix} Xw \\ Yw \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \cdot \begin{bmatrix} xc \\ yc \end{bmatrix} \quad \cdots (1)$$

【００３４】ただし、頭部の動きによる瞳孔中心位置の移動量ΔＰ＝（Δｘ，Δｙ）が頭部移動量算出部２Ｇから瞳孔中心法演算部２Ｄへ送り込まれた場合、瞳孔中心位置Ｐｓは、頭が動いた量に応じて本来の瞳孔中心位置Ｐｕ＝（ｘｒ，ｙｒ）から瞳孔中心位置の移動量ΔＰだけズレていることになるので、頭部移動量算出部２Ｇは、移動量ΔＰのズレを勘案して次の演算式（２）に従って頭部の動きによる誤差が排除された正確な視線位置ＰＴ（Ｘｖ，Ｙｖ）を算出する再演算を実行することになる。なお、ｘｒ＝ｘｃ＋Δｘ，ｙｒ＝ｙｃ＋Δｙであり、また移動量ΔＰ＝（Δｘ，Δｙ）は座標の向きに応じて正または負の数値となる。

【００３５】なお、瞳孔中心法演算部２Ｄにより求め直した視線位置は、パーソナルコンピュータ３へ送出される。従って、実施例の場合、角膜反射法演算部２Ｅの検出結果に基づき検出対象の眼球のある頭部の動きに起因する誤差が除去された瞳孔中心法演算手段による検出結果を求め直す検出結果再演算手段は、頭部移動量算出部２Ｇおよび瞳孔中心法演算部２Ｄとから構成されていることになる。

【００３６】

【数２】

$$\begin{bmatrix} Xv \\ Yv \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \cdot \begin{bmatrix} xc+\Delta x \\ yc+\Delta y \end{bmatrix} \quad \cdots (2)$$

【００３７】また、視線検出装置２は、瞳孔中心法演算部２Ｄによる検出結果からオペレータＭが瞬きしたことを検知する瞬き検知部２Ｈを備えており、瞬き検知部２Ｈはオペレータの眼の瞬きを検知すると直ちにパーソナルコンピュータ３へ瞬き発生を知らせる信号を送出する。

【００３８】一方、パーソナルコンピュータ３は瞳孔中心法演算部２Ｄから送出された視線位置に従って、図４に示すように、ヘッドウマントディスプレイ４の入力操作用画面ＰＡに視線位置を示すカーソル状のマーカｍｋを重畳表示させる。マーカｍｋは、オペレータＭの視線変化に従って入力操作用画面ＰＡの上を移動する構成になっている。他方、パーソナルコンピュータ３は、瞬き検知部２Ｈから瞬き発生を知らせる信号を受信すると、図５に示すように、マーカｍｋが位置する操作キー（又はアイコン）ｎｋに対して入力操作が行われたと判断する。

【００３９】このように、実施例のシステムの場合、オペレータＭは視線と瞬きでパーソナルコンピュータ３の入力操作が行えるので、キーボードの操作が全く出来ない重度の障害者でも寝たままでパーソナルコンピュータ３とコミュニケーション（対話）することが可能となる。

【００４０】続いて、以上に述べた構成を有する実施例のシステムによるコミュニケーションの実行プロセスを、図面を参照しながら説明する。図６は実施例のシステムによるコミュニケーションの進行状況を示すフローチャートである。

【００４１】なお、以下では、オペレータＭにはヘッドマウントディスプレイ４が装着された後、入力操作用画面ＰＡの上の視線位置とその瞳孔中心位置の相関関係に相当する係数としてのＡＢＣＤを要素とするマトリックスは既に求出されて準備が全て終わった段階にあるものとして説明する。

【００４２】〔ステップＳ１〕光学式撮像機器１によりオペレータＭの眼球を撮影して視線検出装置２へ眼球画像を送り込む。

【００４３】〔ステップＳ２〕３値化回路２Ａにより取り込まれた眼球画像が３値化された後、３値化画像から瞳孔抽出部２Ｂにより瞳孔中心位置が求められるとともに、反射像抽出部２Ｂにより反射像の位置が求められる。

【００４４】〔ステップＳ３〕瞳孔中心法演算部２Ｄにより瞳孔中心位置から視線位置が求められるとともに、角膜反射演算部２Ｅにより瞳孔中心位置と反射像の位置から視線位置が検出される。

【００４５】〔ステップＳ４〕検出結果差判定部２Ｆにより両演算部２Ｄ，２Ｅの視線位置の検出結果の差が一定時間継続して所定範囲内であるか否かが判定される。判定結果が肯定であれば、ステップＳ７に飛び、判定結果が否定であれば、次のステップＳ５に進む。

【００４６】〔ステップＳ５〕頭部移動量算出部２Ｇによりオペレータの頭の動きによる瞳孔中心の移動量ΔＰが求出される。

【００４７】〔ステップＳ６〕瞳孔中心法演算部２Ｄがオペレータの頭の動きによる瞳孔中心の移動量ΔＰを勘案して視線位置ＰＴを求出し直す。

【００４８】〔ステップＳ７〕瞳孔中心法演算部２Ｄにより求出された視線位置Ｐｔ又は視線位置ＰＴがパーソナルコンピュータ３に送り込まれる。

【００４９】〔ステップＳ８〕瞬き検出部２Ｈによりオペレータの瞬きが検知された場合は次のステップＳ９へ進み、オペレータの瞬きが検知されなかった場合はステップＳ１０へ飛ぶ。

【００５０】〔ステップＳ９〕瞬き検出部２Ｈから瞬き発生を知らせる信号がパーソナルコンピュータ３に送り込まれて視線位置に対応した入力操作が実行される。

【００５１】〔ステップＳ１０〕視線位置の検出を継続する場合はステップＳ１に戻り、以下のステップを繰り返す。視線位置の検出を継続しない場合はコミュニケーションは終了となる。

【００５２】以上に述べたように、実施例においては、取り込んだ眼球画像に対して瞳孔中心法と瞳孔－角膜反射法の各アルゴリズムにより算出された二つの各検出結果の差が予め設定した所定範囲内に納まっていなくて、

オペレータMの頭部の動きに起因する誤差が存在する場合、頭部の動きによる瞳孔中心位置の移動量ΔPを求めてオペレータMの頭部の動きに起因する誤差を除いた視線位置を求め直す再演算が行われる構成となっている。その結果、瞳孔中心法のアルゴリズムによる的確な検出は常に行われており、眼球の回転角や撮像用照明光の取り付け位置に左右されることもなく、オペレータMの眼球の正確な視線位置が常に検出できることになる。

【0053】この発明は、上記実施の形態に限られることはなく、下記のように変形実施することができる。

【0054】（1）実施例では、眼球画像を3値化処理する構成であったが、必要な位置検出が可能であるなら眼球画像を2値化処理する構成を採用するようにしてもよい。

【0055】（2）実施例では、瞬きのあったことで視線位置の確定を行う構成であったが、スイッチ操作や視線継続時間によって視線位置の確定を行う構成のものが、変形例として挙げられる。

【0056】（3）実施例の場合、視線位置の検出結果がコンピュータの入力操作に利用される構成であったが、この発明においては、視線位置の検出結果はコンピュータの入力操作以外のことに利用される構成であってもよいし、単に視線位置の検出結果を求めるだけの構成であってもよい。

【0057】

【発明の効果】以上に詳述したように、請求項1の発明の視線検出方法によれば、光学式撮像手段により取り込んだ眼球画像に対して瞳孔中心法のアルゴリズムと瞳孔－角膜反射法のアルゴリズムの両アルゴリズムそれぞれによって二つ視線検出結果を得るとともに、二つの検出結果の差が予め設定した所定範囲内に納まっていなくて検出対象の眼球のある頭部の動きに起因する誤差が生じた場合は、瞳孔－角膜反射法のアルゴリズムの検出結果に基づき再演算が行われて検出対象の眼球のある頭部の動きに起因する誤差が除かれた瞳孔中心法のアルゴリズムによる検出結果が得られる構成を備えており、瞳孔中心法のアルゴリズムによる的確な検出は常に行われるので、眼球の回転角や撮像用照明光の取り付け位置に左右されることなく、検出対象の眼球の正確な視線位置が常に検出できることになる。

【0058】さらに、請求項2の発明の視線検出装置によれば、請求項1の発明の方法を実施することによって、検出対象の眼球の正確な視線位置を常に検出することができる。

【0059】また、請求項3の発明の視線検出装置によれば、常に正確に検出される視線位置がコンピュータの入力操作用として利用される構成となっているので、コンピュータの入力操作がいつも間違いなく行われる。

【0060】また、請求項4の発明の視線検出装置によれば、コンピュータからの指令に従ってヘッドマウントディスプレイに表示される入力操作用画面に眼球の視線が向けられる構成となっているので、ヘッドマウントディスプレイに表示中の入力操作用画面から眼球の視線でもってコンピュータ操作のための入力を行うことが可能となる。

【図面の簡単な説明】

【図1】この発明の視線検出装置の一例を用いたコンピュータコミュニケーションシステムの全体構成を示すブロック図である。

【図2】実施例のシステムのコンピュータの入力操作用画面の一例を示す図である。

【図3】実施例の眼球画像においてオペレータ頭部の動きに伴って生じる瞳孔中心位置の変化を示す図である。

【図4】実施例のシステムのコンピュータの入力操作用画面の他の例を示す図である。

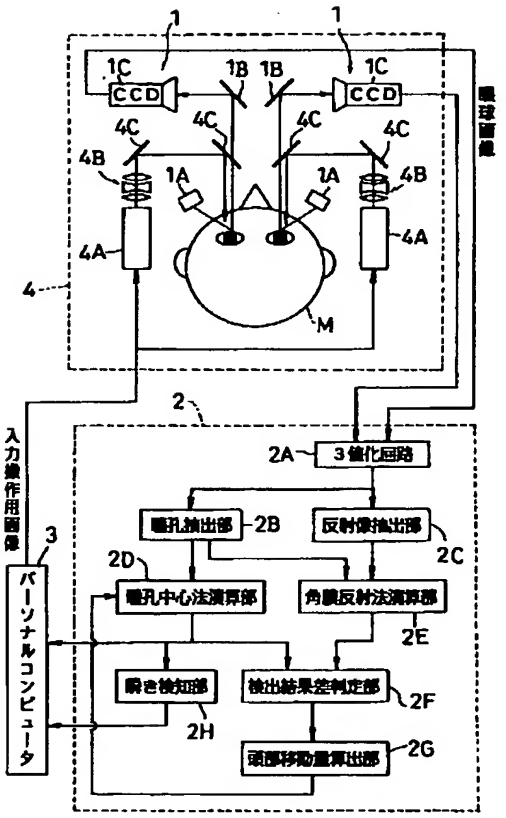
【図5】実施例のシステムのコンピュータの入力操作用画面の他の例を示す図である。

【図6】実施例のシステムによるコミュニケーションの進行状況を示すフローチャートである。

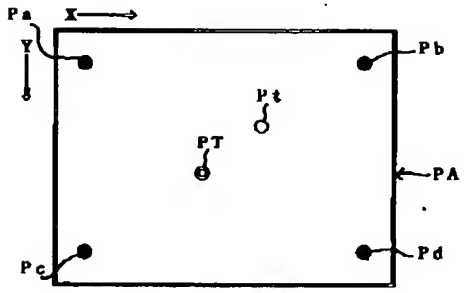
【符号の説明】

1	…光学式撮像機器
2	…視線検出装置
2D	…瞳孔中心法演算部
2E	…角膜反射法演算部
2F	…検出結果差判定部
2G	…頭部移動量算出部
3	…パーソナルコンピュータ
4	…ヘッドマウントディスプレイ
PA	…入力操作用画面
PT，Pt	…視線位置
M	…オペレータ

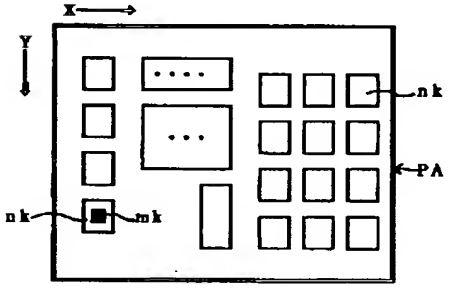
【図1】


1
1C
CCD
1B
4C
4B
1A
4A
4
M
2
2A
3値化回路
瞳孔抽出部
2B
反射像抽出部
2C
2D
瞳孔中心法演算部
角膜反射法演算部
2E
瞬き検知部
2H
検出結果妥当判定部
2F
頭部移動量算出部
2G
3
パーソナルコンピュータ
入力操作用画像
環境画像

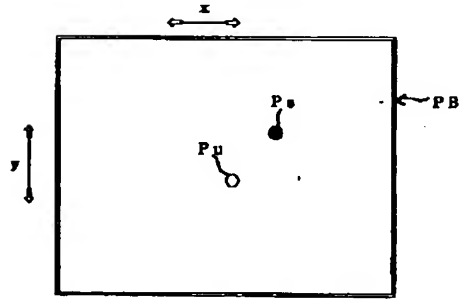
【図2】


Pa
X
Y
Pb
Pt
PT
PA
Pc
Pd

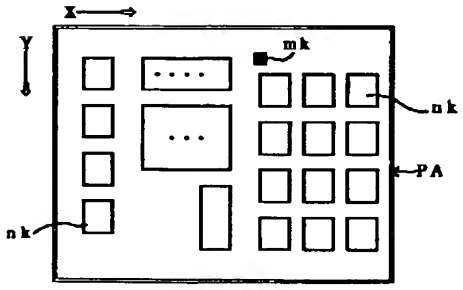
【図5】


X
Y
nk
PA
nk
mk

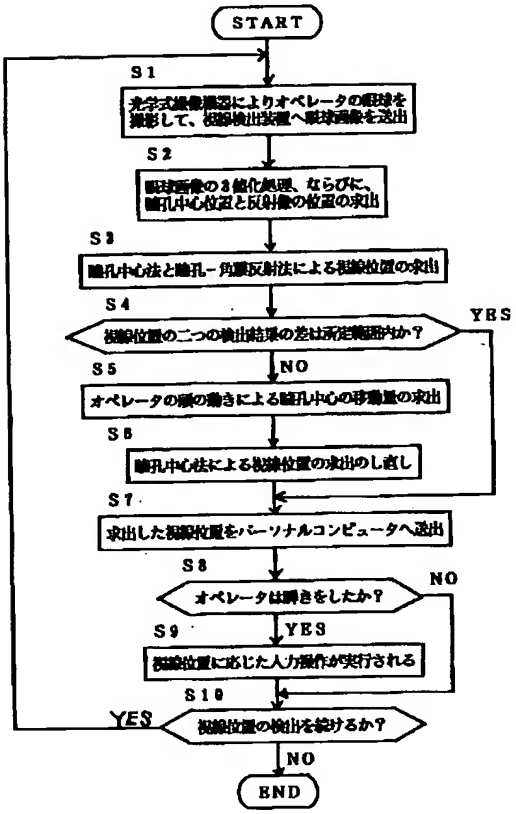
【図3】


x
Ps
PB
Pu
y

【図4】


X
Y
mk
nk
PA
nk

【図6】


START
S1
光学式撮像機器によりオペレータの眼球を撮影して、視線検出装置へ眼球画像を送出
S2
眼球画像の2値化処理、ならびに、瞳孔中心位置と反射像の位置の求出
S3
瞳孔中心法と瞳孔−角膜反射法による視線位置の求出
S4
視線位置の二つの検出結果の差は所定範囲内か？
YES
NO
S5
オペレータの頭の動きによる瞳孔中心の移動量の求出
S6
瞳孔中心法による視線位置の求出のし直し
S7
求出した視線位置をパーソナルコンピュータへ送出
S8
オペレータは瞬きをしたか？
NO
YES
S9
視線位置に応じた入力操作が実行される
S10
視線位置の検出を続けるか？
YES
NO
END

* NOTICES *

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CLAIMS

[Claim(s)]
[Claim 1] In the look detection approach of detecting the look location of an eyeball based on the eyeball image photoed by the optical image pick-up means The operation process in which a look detection result is obtained to the same eyeball image with each of both algorithms of the algorithm of a pupil core method, and the algorithm of a pupil-cornea reflection method, If the judgment result of the detection result difference judging process in which it judges whether it is restored to predetermined within the limits which the difference of the detection result by both algorithms set up beforehand, and a detection result difference judging process is no The look detection approach characterized by having the detection result re-operation process in which the re-operation for researching for the detection result by the algorithm of the pupil core method the error resulting from a motion of the head which has an eyeball for detection based on the detection result of the algorithm of a pupil-cornea reflection method was removed is performed.
[Claim 2] In the look detection equipment constituted so that the look location of an eyeball might be detected based on the eyeball image photoed by the optical image pick-up means A pupil core method operation means to obtain a look detection result from an eyeball image according to the algorithm of a pupil core method, A cornea reflection method operation means to obtain a look detection result from an eyeball image according to the algorithm of a pupil-cornea reflection method, If the judgment result of a detection result difference judging means to judge whether it is restored to predetermined within the limits which the difference of the detection result by said both operation means set up beforehand, and a detection result difference judging means is no Look detection equipment characterized by having a detection result re-operation means to perform the re-operation for researching for the detection result by pupil core method operation means by which the error resulting from a motion of the head which has an eyeball for detection based on the detection result of a cornea reflection method operation means was removed.
[Claim 3] Look detection equipment constituted in look detection equipment according to claim 2 so that the detection result of a look location may be used as an object for the alter operation of a computer.

[Claim 4] Look detection equipment constituted so that the look of an eyeball may be turned to said screen for alter operation of the head mount display which displays the screen for alter operation at least according to the command from a computer in look detection equipment according to claim 3.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to the approach and equipment which detect the look location (the direction of a look) of an eyeball based on the eyeball image captured using the optical image pick-up means, especially relates to a technique to always detect the look location where the eyeball for detection is exact.
[0002]
[Description of the Prior Art] As an approach of detecting the look location of an eyeball, it is usually supposed that a pupil core method and a pupil-cornea reflection method are especially useful. A pupil core method is the technique of using that a pupil core moves according to rotation of the eyeball by change of a look location, measuring the center position of a pupil, and ****(ing) a look location simply. the pupil-cornea reflection method uses that the virtual image (reflected image) produced in the light reflex on the front face of a cornea moves according to rotation of the eyeball by change of a look location, measures the center position and pupil center position of a virtual image on the front face of a cornea, and **** a look location from the relation of both locations -- it is technique.
[0003] It faces actually ****(ing) a look location, and the eyeball for detection is photoed with an optical image pick-up means, the eyeball image is captured, and a look location is determined by analyzing the eyeball image captured according to the algorithm of a pupil core method or a pupil-cornea reflection method.
[0004] Since the movement magnitude of the pupil center position accompanying change of a look location is large in the case of a pupil core method, there is an advantage of being easy to detect a look location. Since migration of the pupil center position by rotation of an eyeball and migration of the pupil center position by motion of a head are separable to some extent in the case of a pupil-cornea reflection method, even if the head is not being fixed completely, there is an advantage that a look location is detectable.
[0005]
[Problem(s) to be Solved by the Invention] However, there is a problem that the look location where the eyeball for detection is exact cannot always detect by the detection approach by the above-mentioned pupil core method or the detection approach by the pupil-cornea reflection method, either.
[0006] That is, since migration of the pupil center position by rotation of an eyeball and migration of the pupil center position by motion of a head are inseparable even if it is easy to carry out detection in the case of the detection approach by the pupil core method, when there is a motion of a head, there is a problem that this cannot serve as an error and cannot detect a look location correctly.
[0007] Moreover, in the case of the detection approach by the pupil-cornea reflection method, a virtual image is not formed in a cornea front face depending on the installation location of the angle of rotation of an eyeball, or the illumination light for an image pick-up, but there is a problem that a look location is undetectable.
[0008] This invention makes it a technical problem to offer the look detection approach which the look

location where the eyeball for detection is exact can always detect, and its equipment in view of the above-mentioned situation.
[0009]
[Means for Solving the Problem] In order to solve said technical problem, the look detection approach concerning invention of claim 1 In the look detection approach of detecting the look location of an eyeball based on the eyeball image photoed by the optical image pick-up means The operation process in which a look detection result is obtained to the same eyeball image with each of both algorithms of the algorithm of a pupil core method, and the algorithm of a pupil-cornea reflection method, If the judgment result of the detection result difference judging process in which it judges whether it is restored to predetermined within the limits which the difference of the detection result by both algorithms set up beforehand, and a detection result difference judging process is no It is characterized by having the detection result re-operation process in which the re-operation for researching for the detection result by the algorithm of the pupil core method the error resulting from a motion of the head which has an eyeball for detection based on the detection result of the algorithm of a pupil-cornea reflection method was removed is performed.
[0010] Furthermore, the look detection equipment concerning invention of claim 2 In the look detection equipment constituted so that the look location of an eyeball might be detected based on the eyeball image photoed by the optical image pick-up means A pupil core method operation means to obtain a look detection result from an eyeball image according to the algorithm of a pupil core method, A cornea reflection method operation means to obtain a look detection result from an eyeball image according to the algorithm of a pupil-cornea reflection method, If the judgment result of a detection result difference judging means to judge whether it is restored to predetermined within the limits which the difference of the detection result by said both operation means set up beforehand, and a detection result difference judging means is no It is characterized by having a detection result re-operation means to perform the re-operation for researching for the detection result by pupil core method operation means by which the error resulting from a motion of the head which has an eyeball for detection based on the detection result of a cornea reflection method operation means was removed.
[0011] Moreover, invention of claim 3 is characterized by constituting the detection result of a look location so that it may be used as an object for the alter operation of a computer in look detection equipment according to claim 2.
[0012] Moreover, invention of claim 4 is characterized by being constituted so that the look of an eyeball may be turned to said screen for alter operation of the head mount display which displays the screen for alter operation at least according to the command from a computer in look detection equipment according to claim 3.
[0013] The operation in [Function], next the look detection equipment concerning this invention is explained. When the look location (the direction of a look) of an eyeball is detected by the approach of this invention, After photoing first the eyeball image of the eyeball which is a candidate for detection with an optical image pick-up means and incorporating Next, after obtaining two look detection results to the captured eyeball image by the operation by each of both algorithms of the algorithm of a pupil core method, and the algorithm of a pupil-cornea reflection method, the difference of two obtained detection results judges whether it is restored to predetermined within the limits set up beforehand. When the difference of the detection result of both algorithms is not restored to predetermined within the limits (in the case of negation), the error will have arisen in the detection result by the algorithm of a pupil core method by migration of the pupil center position by motion of a head with the eyeball for detection.
[0014] Then, in the approach of this invention, if a judgment result is negation, the detection result by the algorithm of the pupil core method the error resulting from a motion of the head which a re-operation is performed based on the detection result of the algorithm of a pupil-cornea reflection method, and has an eyeball for detection was removed will be researched for, and an exact look location will be ****(ed). That is, since migration of the pupil center position by rotation of an eyeball and migration of the pupil center position by motion of the head which has the eyeball for detection are

separable in the case of the algorithm of a pupil-cornea reflection method, the movement magnitude of the pupil center position by motion of a head is calculated, and the error resulting from a motion of a head is removed by amending the pupil center position in the algorithm of a pupil core method using this.
[0015] In addition, when the difference of the detection result of both algorithms is restored to predetermined within the limits (in the case of affirmation), each detection result of the look location by both the algorithms of a pupil core method and a pupil-cornea reflection method will be called accuracy.

[0016] Therefore, in the look detection approach of this invention, the look location where an eyeball is exact can always detect, without being influenced by the installation location of the angle of rotation of an eyeball, or the illumination light for an image pick-up since the exact detection result by the algorithm of a pupil core method is always obtained.
[0017] Furthermore, in the case of the equipment of invention of claim 2, the look location of the eyeball for detection is always correctly detectable by inventing claim 1.
[0018] Moreover, in the case of the look detection equipment of claim 3, according to the look location always detected correctly, alter operation of a computer is performed always rightly.
[0019] Moreover, in the case of the look detection equipment of claim 4, the input for computer operation is performed from the screen for alter operation on display as it is also with the look of the eyeball turned to the screen for alter operation displayed on a head mount display according to the command from a computer (computer operator).
[0020]
[Embodiment of the Invention] Then, one example of this invention is explained, referring to a drawing. Drawing 1 is the block diagram showing the whole computer communication system configuration which used an example of the look detection equipment of claims 2-4. Moreover, the look detection equipment currently arranged into the system of drawing 1 is equipment which detects a look location (the direction of a look) by carrying out an example of the look detection approach of claim 1.
[0021] The computer communication system of an example So that the look location of an eyeball may be detected based on Operator's M eyeball image photoed by the optical image pick-up device 1 which photos Operator's M eyeball image, and the optical image pick-up device 1 Configuration **** look detection equipment 2, The personal computer 3 with which alter operation is made according to the detection result of the look location by look detection equipment 2, It has the head mount display (HMD) 4 with which the screen for alter operation is displayed at least according to the command from a personal computer 3. While the look location of Operator's M eyeball turned to the screen for alter operation of a head mount display 4 is detected by look detection equipment 2 It has the composition that alter operation is made to a personal computer 3 according to the detected look location, and communication is performed between Operator M and a computer 3.
[0022] Hereafter, the configuration of each part of the computer communication system of an example is explained concretely.
[0023] The optical image pick-up device 1 consists of source of infrared light 1A, half mirror 1B, and CCD camera 1C which are installed in the head mount display 4, and while Operator's M eyeball illuminated with the exposure light of source of infrared light 1A is photoed by CCD camera 1C through half mirror 1B, the photoed eyeball image has composition sent out to look detection equipment 2 from CCD camera 1C. In addition, the optical image pick-up device 1 is formed one pair in right-and-left both eyes.
[0024] LCD(liquid crystal display)4A which provides the operator M putting on a head mount display 4 with the screen for alter operation, and optical-system 4for display B and half mirror 4C of a pair were prepared in right-and-left both eyes, respectively, a picture signal is offered [well-known] from a personal computer 3 at LCD4A, and the enlarged display of the screen for alter operation is carried out to the view of the operator M who equips. Images, such as an actuation key and an icon, project on the screen for alter operation at a position. Since in the case of the enlarged display by the head mount display 4 an angle of visibility is expanded and the movement magnitude of the look of the operator at

the time of migration of a fixation point becomes large, there is an advantage whose detection precision of a look location improves.
[0025] 3 value-ized circuit 2A which look detection equipment 2 3-value--ization-processes the captured eyeball image according to the "threshold" set up beforehand, and obtains 3 value-ized image, If it has pupil extract section 2B which **** a pupil center position, and reflected image extract section 2C which **** the location (core) of the reflected image (virtual image) produced from 3 value-ized image on a cornea front face from 3 value-ized image and one eyeball image is newly captured It has the composition that a pupil center position and the location of a reflected image are ****(ed) immediately. In addition, in 3 value-ized image, the darkest field is a pupil image and the brightest field corresponds to a reflected image.
[0026] Furthermore, look detection equipment 2 is equipped with pupil core method operation part 2D which **** a look location according to the algorithm of a pupil core method from an eyeball image, and cornea reflection method operation part 2E which **** a look location according to the algorithm of a pupil-cornea reflection method from an eyeball image. That is, pupil core method operation part 2D computes a look location comparatively simply from the pupil center position called for by pupil extract section 2B, and cornea reflection method operation part 2E computes a look location from the pupil center position called for by pupil extract section 2B, and the location of the reflected image searched for by reflected image extract section 2C.
[0027] The look location computed by both [these] operation part 2D and 2E corresponds to the screen for alter operation displayed in a head mount display 4. That is, the calibration of a look location is beforehand performed to the standard point of the screen for alter operation, and the look location computed by both operation part 2D and 2E has composition matched with the fixation point on the screen for alter operation.
[0028] As shown in drawing 2 , after specifically asking for the pupil center position on an eyeball image in case an eyeball gazes at standard point Pa-Pd which is four of the four directions whose locations of Screen PA for alter operation are known in order and a look is in each of each standard point Pa-Pd, Furthermore the correlation of the coordinate and pupil center position of four standard point Pa-Pd in Screen PA for alter operation, a pupil center position, and a reflected image location is searched for beforehand, and the pupil center position at the time of an observation is changed into the look location which corresponds on the screen for alter operation according to this correlation. In addition, in the case of the screen for alter operation of an example, it has composition which shows a look location by XY rectangular coordinates which make the upper left a zero.
[0029] And it has detection result difference judging section 2F which judge whether look detection equipment 2 carried out fixed time amount continuation at predetermined within the limits which the difference of the detection result of both algorithms set up beforehand, and it is settled. In negation of the judgment result by detection result difference judging section 2F (not restored to predetermined within the limits), in the look location computed by pupil core method operation part 2D, the error resulting from a motion of Operator's M head is included, and a detection result will not be exact.
[0030] On the contrary, in affirmation of the judgment result by detection result difference judging section 2F (restored to predetermined within the limits), there is no motion in Operator's M head, and the error resulting from a motion of Operator's M head will not be included in the look location computed by both operation part 2D and 2E, but the detection result will be exact. In this case, the look location computed by pupil core method operation part 2D is sent out immediately to a personal computer 3.
[0031] Furthermore, look detection equipment 2 is equipped with head movement magnitude calculation section 2G which compute the movement magnitude of Operator's M head from the detection result by cornea reflection method operation part 2E. That is, since migration of the pupil center position by rotation of an eyeball and migration of the pupil center position by motion of a head are separable in general in the case of a pupil-cornea reflection method When the judgment result by detection result difference judging section 2F is negation, head movement magnitude calculation section 2G It has composition which computes the movement magnitude (on an eyeball image) (deltax, delta y) of the pupil center position by motion of a head in the form [like] which carries out inverse transformation

processing of the detection result by cornea reflection method operation part 2E, and is sent into pupil core method operation part 2D.
[0032] As shown in drawing 3 , when it is more specifically pupil center position Ps= (xc, yc) on the eyeball image PB in the case of pupil core method operation part 2D, as shown in drawing 2 , according to the following operation expression (1), look location Pt= (Xw, Yw) in Screen PA for alter operation is computed. The matrix which uses ABCD of operation expression (1) as an element corresponds to the correlation between the pupil center position Ps on the eyeball image PB called for as mentioned above based on four standard point Pa-Pd in Screen PA for alter operation, and the look location Pt on Screen PA for alter operation (correspondence relation).
[0033]
[Equation 1]

$$\begin{bmatrix} Xw \\ Yw \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \cdot \begin{bmatrix} xc \\ yc \end{bmatrix} \quad \cdots (1)$$

[0034] When movement magnitude deltaP= (deltax, delta y) of the pupil center position by motion of a head is sent into pupil core method operation part 2D from head movement magnitude calculation section 2G, however, the pupil center position Ps Since only the movement magnitude deltaP of a pupil center position will have shifted from original pupil center position Pu= (xr, yr) according to the amount by which the head moved, head movement magnitude calculation section 2G The re-operation which computes the exact look location PT (Xv, Yv) where gap of movement magnitude deltaP was taken into consideration, and the error by motion of a head was eliminated according to the following operation expression (2) will be performed. In addition, it is xr=xc+delta x and yr=yc+deltay and movement magnitude deltaP= (deltax, delta y) becomes forward or a negative-number value according to the sense of a coordinate.
[0035] In addition, the look location for which it reasked by pupil core method operation part 2D is sent out to a personal computer 3. Therefore, in the case of the example, a detection result re-operation means to research for the detection result by pupil core method operation means by which the error resulting from a motion of the head which has an eyeball for detection based on the detection result of cornea reflection method operation part 2E was removed will consist of head movement magnitude calculation section 2G and pupil core method operation part 2D.
[0036]
[Equation 2]

$$\begin{bmatrix} Xv \\ Yv \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \cdot \begin{bmatrix} xc+\Delta x \\ yc+\Delta y \end{bmatrix} \quad \cdots (2)$$

[0037] Moreover, look detection equipment 2 is equipped with blink detection section 2H which detect Operator M having winked and having carried out from the detection result by pupil core method operation part 2D, and blink detection section 2H send out the signal which winks to a personal computer 3 immediately and tells generating, if the blink of Operator's M eye is detected.
[0038] On the other hand, according to the look location sent out from pupil core method operation part 2D, a personal computer 3 indicates by superposition the cursor-like marker mk who shows a look location to Screen PA for alter operation of the head UMANTO display 4, as shown in drawing 4 . Marker mk has composition which moves in the Screen PA top for alter operation according to look change of Operator M. On the other hand, if the signal which a personal computer 3 winks from blink detection section 2H, and tells generating is received, as shown in drawing 5 , it will be judged that alter operation was performed to the actuation key (or icon) nk in which Marker mk is located.
[0039] thus, since in the case of the system of an example Operator M winks with a look, it comes out and alter operation of a personal computer 3 can be performed, it becomes possible to communicate with a personal computer 3, while the serious trouble back tone who cannot do actuation of a keyboard at all

had also gone to sleep (dialogue).
[0040] Then, the activation process of communication by the system of the example which has the configuration described above is explained, referring to a drawing. Drawing 6 is a flow chart which shows the advance situation of communication by the system of an example.
[0041] In addition, below, after Operator M is equipped with a head mount display 4, it explains as a thing in the phase which the matrix which uses ABCD as a multiplier equivalent to the correlation of the look location and pupil center position on Screen PA for alter operation as an element was already **** (ed), and all preparations finished.
[0042] [Step S1] Operator's M eyeball is photoed by the optical image pick-up device 1, and an eyeball image is sent into look detection equipment 2.
[0043] [Step S2] After the eyeball image captured by 3 value-ized circuit 2A is formed into 3 values, while a pupil center position is called for by pupil extract section 2B from 3 value-ized image, the location of a reflected image is called for by reflected image extract section 2B.
[0044] [Step S3] While a look location is called for from a pupil center position by pupil core method operation part 2D, a look location is detected by corneal-reflex operation part 2E from a pupil center position and the location of a reflected image.
[0045] [Step S4] The difference of both operation part 2D and the detection result of the look location of 2E carries out fixed time amount continuation by detection result difference judging section 2F, and it is judged whether it is predetermined within the limits. If a judgment result is affirmation, it will fly to step S7, and if a judgment result is negation, it will progress to the following step S5.
[0046] [Step S5] Movement magnitude deltaP based on [by motion of Operator's M head] pupils is ****(ed) by head movement magnitude calculation section 2G.
[0047] [Step S6] Pupil core method operation part 2D takes into consideration movement magnitude deltaP based on [by motion of Operator's M head] pupils, and re**** the look location PT.
[0048] [Step S7] The look location Pt or the look location PT ****(ed) by pupil core method operation part 2D is sent into a personal computer 3.
[0049] [Step S8] When a blink of Operator M is detected by blink detecting-element 2H, it progresses to the following step S9, and when a blink of Operator M is not detected, it flies to step S10.
[0050] [Step S9] The signal which winks from blink detecting-element 2H, and tells generating is sent into a personal computer 3, and alter operation corresponding to a look location is performed.
[0051] [Step S10] When continuing detection of a look location, return and the following steps are repeated to step S1. Communication is ended when not continuing detection of a look location.
[0052] It is not restored to predetermined within the limits which the difference of each two detection results computed by each algorithm of a pupil core method and a pupil-cornea reflection method to the captured eyeball image in the example set up beforehand as stated above. When the error resulting from a motion of Operator's M head exists, it has the composition that the re-operation which reasks for the look location except the error which originates in a motion of Operator's M head in quest of movement magnitude deltaP of the pupil center position by motion of a head is performed. Consequently, exact detection by the algorithm of a pupil core method is always performed, and the look location where Operator's M eyeball is exact can always detect, without being influenced by the installation location of the angle of rotation of an eyeball, or the illumination light for an image pick-up.
[0053] This invention is not restricted to the gestalt of the above-mentioned implementation, and can carry out deformation implementation as follows.
[0054] (1) If required location detection is possible, you may make it adopt in the example, the configuration which binary--ization-processes an eyeball image, although it was the configuration of 3-value--ization-processing an eyeball image.
[0055] (2) In the example, although it was the configuration of deciding a look location because there was a blink, the thing of a configuration of deciding a look location by switch actuation or look duration is mentioned as a modification.
[0056] (3) In the case of the example, it was the configuration that the detection result of a look location was used for the alter operation of a computer, but in this invention, the detection result of a look

location may be a configuration used for things other than the alter operation of a computer, and may be only a configuration which only searches for the detection result of a look location.
[0057]
[Effect of the Invention] As explained in full detail above, while obtaining a 2 look detection result to the eyeball image captured with the optical image pick-up means with each of both algorithms of the algorithm of a pupil core method, and the algorithm of a pupil-cornea reflection method according to the look detection approach of invention of claim 1 When the error resulting from a motion of the head where the difference of two detection results is not restored to predetermined within the limits set up beforehand, and the eyeball for detection has it arises It has the configuration from which the detection result by the algorithm of the pupil core method the error resulting from a motion of the head which a re-operation is performed based on the detection result of the algorithm of a pupil-cornea reflection method, and has an eyeball for detection was removed is obtained. The look location where the eyeball for detection is exact can always detect, without being influenced by the installation location of the angle of rotation of an eyeball, or the illumination light for an image pick-up since exact detection by the algorithm of a pupil core method is always performed.
[0058] Furthermore, according to the look detection equipment of invention of claim 2, the look location where the eyeball for detection is exact is detectable by enforcing the approach of invention of claim 1.
[0059] Moreover, since the look location always detected correctly has composition used as an object for the alter operation of a computer according to the look detection equipment of invention of claim 3, alter operation of a computer is performed always rightly.
[0060]

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TECHNICAL FIELD

[Field of the Invention] This invention relates to the approach and equipment which detect the look location (the direction of a look) of an eyeball based on the eyeball image captured using the optical image pick-up means, especially relates to a technique to always detect the look location where the eyeball for detection is exact.

[Translation done.]

PRIOR ART

[Description of the Prior Art] As an approach of detecting the look location of an eyeball, it is usually supposed that a pupil core method and a pupil-cornea reflection method are especially useful. A pupil core method is the technique of using that a pupil core moves according to rotation of the eyeball by change of a look location, measuring the center position of a pupil, and ****(ing) a look location simply. the pupil-cornea reflection method uses that the virtual image (reflected image) produced in the light reflex on the front face of a cornea moves according to rotation of the eyeball by change of a look location, measures the center position and pupil center position of a virtual image on the front face of a cornea, and **** a look location from the relation of both locations -- it is technique.
[0003] It faces actually ****(ing) a look location, and the eyeball for detection is photoed with an optical image pick-up means, the eyeball image is captured, and a look location is determined by analyzing the eyeball image captured according to the algorithm of a pupil core method or a pupil-cornea reflection method.
[0004] Since the movement magnitude of the pupil center position accompanying change of a look location is large in the case of a pupil core method, there is an advantage of being easy to detect a look location. Since migration of the pupil center position by rotation of an eyeball and migration of the pupil center position by motion of a head are separable to some extent in the case of a pupil-cornea reflection method, even if the head is not being fixed completely, there is an advantage that a look location is detectable.

[Translation done.]

EFFECT OF THE INVENTION

[Effect of the Invention] As explained in full detail above, while obtaining a 2 look detection result to the eyeball image captured with the optical image pick-up means with each of both algorithms of the algorithm of a pupil core method, and the algorithm of a pupil-cornea reflection method according to the look detection approach of invention of claim 1 When the error resulting from a motion of the head where the difference of two detection results is not restored to predetermined within the limits set up beforehand, and the eyeball for detection has it arises It has the configuration from which the detection result by the algorithm of the pupil core method the error resulting from a motion of the head which a re-operation is performed based on the detection result of the algorithm of a pupil-cornea reflection method, and has an eyeball for detection was removed is obtained. The look location where the eyeball for detection is exact can always detect, without being influenced by the installation location of the angle of rotation of an eyeball, or the illumination light for an image pick-up since exact detection by the algorithm of a pupil core method is always performed.
[0058] Furthermore, according to the look detection equipment of invention of claim 2, the look location where the eyeball for detection is exact is detectable by enforcing the approach of invention of claim 1.
[0059] Moreover, since the look location always detected correctly has composition used as an object for the alter operation of a computer according to the look detection equipment of invention of claim 3, alter operation of a computer is performed always rightly.
[0060] Moreover, since it has the composition that the look of an eyeball is turned to the screen for alter operation displayed on a head mount display according to the command from a computer according to the look detection equipment of invention of claim 4, it becomes possible from the screen for alter operation on display to a head mount display to perform the input for computer operation as it is also with the look of an eyeball.

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TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] However, there is a problem that the look location where the eyeball for detection is exact cannot always detect by the detection approach by the above-mentioned pupil core method or the detection approach by the pupil-cornea reflection method, either.
[0006] That is, since migration of the pupil center position by rotation of an eyeball and migration of the pupil center position by motion of a head are inseparable even if it is easy to carry out detection in the case of the detection approach by the pupil core method, when there is a motion of a head, there is a problem that this cannot serve as an error and cannot detect a look location correctly.
[0007] Moreover, in the case of the detection approach by the pupil-cornea reflection method, a virtual image is not formed in a cornea front face depending on the installation location of the angle of rotation of an eyeball, or the illumination light for an image pick-up, but there is a problem that a look location is undetectable.
[0008] This invention makes it a technical problem to offer the look detection approach which the look location where the eyeball for detection is exact can always detect, and its equipment in view of the above-mentioned situation.

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MEANS

[Means for Solving the Problem] In order to solve said technical problem, the look detection approach concerning invention of claim 1 In the look detection approach of detecting the look location of an eyeball based on the eyeball image photoed by the optical image pick-up means The operation process in which a look detection result is obtained to the same eyeball image with each of both algorithms of the algorithm of a pupil core method, and the algorithm of a pupil-cornea reflection method, If the judgment result of the detection result difference judging process in which it judges whether it is restored to predetermined within the limits which the difference of the detection result by both algorithms set up beforehand, and a detection result difference judging process is no It is characterized by having the detection result re-operation process in which the re-operation for researching for the detection result by the algorithm of the pupil core method the error resulting from a motion of the head which has an eyeball for detection based on the detection result of the algorithm of a pupil-cornea reflection method was removed is performed.
[0010] Furthermore, the look detection equipment concerning invention of claim 2 In the look detection equipment constituted so that the look location of an eyeball might be detected based on the eyeball image photoed by the optical image pick-up means A pupil core method operation means to obtain a look detection result from an eyeball image according to the algorithm of a pupil core method, A cornea reflection method operation means to obtain a look detection result from an eyeball image according to the algorithm of a pupil-cornea reflection method, If the judgment result of a detection result difference judging means to judge whether it is restored to predetermined within the limits which the difference of the detection result by said both operation means set up beforehand, and a detection result difference judging means is no It is characterized by having a detection result re-operation means to perform the re-operation for researching for the detection result by pupil core method operation means by which the error resulting from a motion of the head which has an eyeball for detection based on the detection result of a cornea reflection method operation means was removed.
[0011] Moreover, invention of claim 3 is characterized by constituting the detection result of a look location so that it may be used as an object for the alter operation of a computer in look detection equipment according to claim 2.
[0012] Moreover, invention of claim 4 is characterized by being constituted so that the look of an eyeball may be turned to said screen for alter operation of the head mount display which displays the screen for alter operation at least according to the command from a computer in look detection equipment according to claim 3.

[Translation done.]

* NOTICES *

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OPERATION

The operation in [Function], next the look detection equipment concerning this invention is explained. When the look location (the direction of a look) of an eyeball is detected by the approach of this invention, After photoing first the eyeball image of the eyeball which is a candidate for detection with an optical image pick-up means and incorporating Next, after obtaining two look detection results to the captured eyeball image by the operation by each of both algorithms of the algorithm of a pupil core method, and the algorithm of a pupil-cornea reflection method, the difference of two obtained detection results judges whether it is restored to predetermined within the limits set up beforehand. When the difference of the detection result of both algorithms is not restored to predetermined within the limits (in the case of negation), the error will have arisen in the detection result by the algorithm of a pupil core method by migration of the pupil center position by motion of a head with the eyeball for detection.
[0014] Then, in the approach of this invention, if a judgment result is negation, the detection result by the algorithm of the pupil core method the error resulting from a motion of the head which a re-operation is performed based on the detection result of the algorithm of a pupil-cornea reflection method, and has an eyeball for detection was removed will be researched for, and an exact look location will be ****(ed). That is, since migration of the pupil center position by rotation of an eyeball and migration of the pupil center position by motion of the head which has the eyeball for detection are separable in the case of the algorithm of a pupil-cornea reflection method, the movement magnitude of the pupil center position by motion of a head is calculated, and the error resulting from a motion of a head is removed by amending the pupil center position in the algorithm of a pupil core method using this.
[0015] In addition, when the difference of the detection result of both algorithms is restored to predetermined within the limits (in the case of affirmation), each detection result of the look location by both the algorithms of a pupil core method and a pupil-cornea reflection method will be called accuracy.

[0016] Therefore, in the look detection approach of this invention, the look location where an eyeball is exact can always detect, without being influenced by the installation location of the angle of rotation of an eyeball, or the illumination light for an image pick-up since the exact detection result by the algorithm of a pupil core method is always obtained.
[0017] Furthermore, in the case of the equipment of invention of claim 2, the look location of the eyeball for detection is always correctly detectable by inventing claim 1.
[0018] Moreover, in the case of the look detection equipment of claim 3, according to the look location always detected correctly, alter operation of a computer is performed always rightly.
[0019] Moreover, in the case of the look detection equipment of claim 4, the input for computer operation is performed from the screen for alter operation on display as it is also with the look of the eyeball turned to the screen for alter operation displayed on a head mount display according to the command from a computer (computer operator).
[0020]
[Embodiment of the Invention] Then, one example of this invention is explained, referring to a drawing.

Drawing 1 is the block diagram showing the whole computer communication system configuration which used an example of the look detection equipment of claims 2-4. Moreover, the look detection equipment currently arranged into the system of drawing 1 is equipment which detects a look location (the direction of a look) by carrying out an example of the look detection approach of claim 1.
[0021] The computer communication system of an example So that the look location of an eyeball may be detected based on Operator's M eyeball image photoed by the optical image pick-up device 1 which photos Operator's M eyeball image, and the optical image pick-up device 1 Configuration **** look detection equipment 2, The personal computer 3 with which alter operation is made according to the detection result of the look location by look detection equipment 2, It has the head mount display (HMD) 4 with which the screen for alter operation is displayed at least according to the command from a personal computer 3. While the look location of Operator's M eyeball turned to the screen for alter operation of a head mount display 4 is detected by look detection equipment 2 It has the composition that alter operation is made to a personal computer 3 according to the detected look location, and communication is performed between Operator M and a computer 3.
[0022] Hereafter, the configuration of each part of the computer communication system of an example is explained concretely.
[0023] The optical image pick-up device 1 consists of source of infrared light 1A, half mirror 1B, and CCD camera 1C which are installed in the head mount display 4, and while Operator's M eyeball illuminated with the exposure light of source of infrared light 1A is photoed by CCD camera 1C through half mirror 1B, the photoed eyeball image has composition sent out to look detection equipment 2 from CCD camera 1C. In addition, the optical image pick-up device 1 is formed one pair in right-and-left both eyes.
[0024] LCD(liquid crystal display)4A which provides the operator M putting on a head mount display 4 with the screen for alter operation, and optical-system 4for display B and half mirror 4C of a pair were prepared in right-and-left both eyes, respectively, a picture signal is offered [well-known] from a personal computer 3 at LCD4A, and the enlarged display of the screen for alter operation is carried out to the view of the operator M who equips. Images, such as an actuation key and an icon, project on the screen for alter operation at a position. Since in the case of the enlarged display by the head mount display 4 an angle of visibility is expanded and the movement magnitude of the look of the operator at the time of migration of a fixation point becomes large, there is an advantage whose detection precision of a look location improves.
[0025] 3 value-ized circuit 2A which look detection equipment 2 3-value--ization-processes the captured eyeball image according to the "threshold" set up beforehand, and obtains 3 value-ized image, If it has pupil extract section 2B which **** a pupil center position, and reflected image extract section 2C which **** the location (core) of the reflected image (virtual image) produced from 3 value-ized image on a cornea front face from 3 value-ized image and one eyeball image is newly captured It has the composition that a pupil center position and the location of a reflected image are ****(ed) immediately. In addition, in 3 value-ized image, the darkest field is a pupil image and the brightest field corresponds to a reflected image.
[0026] Furthermore, look detection equipment 2 is equipped with pupil core method operation part 2D which **** a look location according to the algorithm of a pupil core method from an eyeball image, and cornea reflection method operation part 2E which **** a look location according to the algorithm of a pupil-cornea reflection method from an eyeball image. That is, pupil core method operation part 2D computes a look location comparatively simply from the pupil center position called for by pupil extract section 2B, and cornea reflection method operation part 2E computes a look location from the pupil center position called for by pupil extract section 2B, and the location of the reflected image searched for by reflected image extract section 2C.
[0027] The look location computed by both [these] operation part 2D and 2E corresponds to the screen for alter operation displayed in a head mount display 4. That is, the calibration of a look location is beforehand performed to the standard point of the screen for alter operation, and the look location computed by both operation part 2D and 2E has composition matched with the fixation point on the

screen for alter operation.
[0028] As shown in drawing 2 , after specifically asking for the pupil center position on an eyeball image in case an eyeball gazes at standard point Pa-Pd which is four of the four directions whose locations of Screen PA for alter operation are known in order and a look is in each of each standard point Pa-Pd, Furthermore the correlation of the coordinate and pupil center position of four standard point Pa-Pd in Screen PA for alter operation, a pupil center position, and a reflected image location is searched for beforehand, and the pupil center position at the time of an observation is changed into the look location which corresponds on the screen for alter operation according to this correlation. In addition, in the case of the screen for alter operation of an example, it has composition which shows a look location by XY rectangular coordinates which make the upper left a zero.
[0029] And it has detection result difference judging section 2F which judge whether look detection equipment 2 carried out fixed time amount continuation at predetermined within the limits which the difference of the detection result of both algorithms set up beforehand, and it is settled. In negation of the judgment result by detection result difference judging section 2F (not restored to predetermined within the limits), in the look location computed by pupil core method operation part 2D, the error resulting from a motion of Operator's M head is included, and a detection result will not be exact.
[0030] On the contrary, in affirmation of the judgment result by detection result difference judging section 2F (restored to predetermined within the limits), there is no motion in Operator's M head, and the error resulting from a motion of Operator's M head will not be included in the look location computed by both operation part 2D and 2E, but the detection result will be exact. In this case, the look location computed by pupil core method operation part 2D is sent out immediately to a personal computer 3.
[0031] Furthermore, look detection equipment 2 is equipped with head movement magnitude calculation section 2G which compute the movement magnitude of Operator's M head from the detection result by cornea reflection method operation part 2E. That is, since migration of the pupil center position by rotation of an eyeball and migration of the pupil center position by motion of a head are separable in general in the case of a pupil-cornea reflection method When the judgment result by detection result difference judging section 2F is negation, head movement magnitude calculation section 2G It has composition which computes the movement magnitude (on an eyeball image) (deltax, delta y) of the pupil center position by motion of a head in the form [like] which carries out inverse transformation processing of the detection result by cornea reflection method operation part 2E, and is sent into pupil core method operation part 2D.
[0032] As shown in drawing 3 , when it is more specifically pupil center position Ps= (xc, yc) on the eyeball image PB in the case of pupil core method operation part 2D, as shown in drawing 2 , according to the following operation expression (1), look location Pt= (Xw, Yw) in Screen PA for alter operation is computed. The matrix which uses ABCD of operation expression (1) as an element corresponds to the correlation between the pupil center position Ps on the eyeball image PB called for as mentioned above based on four standard point Pa-Pd in Screen PA for alter operation, and the look location Pt on Screen PA for alter operation (correspondence relation).
[0033]
[Equation 1]

$$\begin{bmatrix} Xw \\ Yw \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \cdot \begin{bmatrix} xc \\ yc \end{bmatrix} \quad \cdots (1)$$

[0034] When movement magnitude deltaP= (deltax, delta y) of the pupil center position by motion of a head is sent into pupil core method operation part 2D from head movement magnitude calculation section 2G, however, the pupil center position Ps Since only the movement magnitude deltaP of a pupil center position will have shifted from original pupil center position Pu= (xr, yr) according to the amount by which the head moved, head movement magnitude calculation section 2G The re-operation which computes the exact look location PT (Xv, Yv) where gap of movement magnitude deltaP was taken into consideration, and the error by motion of a head was eliminated according to the following operation

expression (2) will be performed. In addition, it is xr=xc+delta x and yr=yc+deltay and movement magnitude deltaP= (deltax, delta y) becomes forward or a negative-number value according to the sense of a coordinate.

[0035] In addition, the look location for which it reasked by pupil core method operation part 2D is sent out to a personal computer 3. Therefore, in the case of the example, a detection result re-operation means to research for the detection result by pupil core method operation means by which the error resulting from a motion of the head which has an eyeball for detection based on the detection result of cornea reflection method operation part 2E was removed will consist of head movement magnitude calculation section 2G and pupil core method operation part 2D.

[0036]

[Equation 2]

$$\begin{bmatrix} Xv \\ Yv \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \cdot \begin{bmatrix} xc+\Delta x \\ yc+\Delta y \end{bmatrix} \quad \cdots (2)$$

[0037] Moreover, look detection equipment 2 is equipped with blink detection section 2H which detect Operator M having winked and having carried out from the detection result by pupil core method operation part 2D, and blink detection section 2H send out the signal which winks to a personal computer 3 immediately and tells generating, if the blink of Operator's M eye is detected.

[0038] On the other hand, according to the look location sent out from pupil core method operation part 2D, a personal computer 3 indicates by superposition the cursor-like marker mk who shows a look location to Screen PA for alter operation of the head UMANTO display 4, as shown in drawing 4 . Marker mk has composition which moves in the Screen PA top for alter operation according to look change of Operator M. On the other hand, if the signal which a personal computer 3 winks from blink detection section 2H, and tells generating is received, as shown in drawing 5 , it will be judged that alter operation was performed to the actuation key (or icon) nk in which Marker mk is located.

[0039] thus, since in the case of the system of an example Operator M winks with a look, it comes out and alter operation of a personal computer 3 can be performed, it becomes possible to communicate with a personal computer 3, while the serious trouble back tone who cannot do actuation of a keyboard at all had also gone to sleep (dialogue).

[0040] Then, the activation process of communication by the system of the example which has the configuration described above is explained, referring to a drawing. Drawing 6 is a flow chart which shows the advance situation of communication by the system of an example.

[0041] In addition, below, after Operator M is equipped with a head mount display 4, it explains as a thing in the phase which the matrix which uses ABCD as a multiplier equivalent to the correlation of the look location and pupil center position on Screen PA for alter operation as an element was already **** (ed), and all preparations finished.

[0042] [Step S1] Operator's M eyeball is photoed by the optical image pick-up device 1, and an eyeball image is sent into look detection equipment 2.

[0043] [Step S2] After the eyeball image captured by 3 value-ized circuit 2A is formed into 3 values, while a pupil center position is called for by pupil extract section 2B from 3 value-ized image, the location of a reflected image is called for by reflected image extract section 2B.

[0044] [Step S3] While a look location is called for from a pupil center position by pupil core method operation part 2D, a look location is detected by corneal-reflex operation part 2E from a pupil center position and the location of a reflected image.

[0045] [Step S4] The difference of both operation part 2D and the detection result of the look location of 2E carries out fixed time amount continuation by detection result difference judging section 2F, and it is judged whether it is predetermined within the limits. If a judgment result is affirmation, it will fly to step S7, and if a judgment result is negation, it will progress to the following step S5.

[0046] [Step S5] Movement magnitude deltaP based on [by motion of Operator's M head] pupils is ****(ed) by head movement magnitude calculation section 2G.

[0047] [Step S6] Pupil core method operation part 2D takes into consideration movement magnitude deltaP based on [by motion of Operator's M head] pupils, and re**** the look location PT.
[0048] [Step S7] The look location Pt or the look location PT ****(ed) by pupil core method operation part 2D is sent into a personal computer 3.
[0049] [Step S8] When a blink of Operator M is detected by blink detecting-element 2H, it progresses to the following step S9, and when a blink of Operator M is not detected, it flies to step S10.
[0050] [Step S9] The signal which winks from blink detecting-element 2H, and tells generating is sent into a personal computer 3, and alter operation corresponding to a look location is performed.
[0051] [Step S10] When continuing detection of a look location, return and the following steps are repeated to step S1. Communication is ended when not continuing detection of a look location.
[0052] It is not restored to predetermined within the limits which the difference of each two detection results computed by each algorithm of a pupil core method and a pupil-cornea reflection method to the captured eyeball image in the example set up beforehand as stated above. When the error resulting from a motion of Operator's M head exists, it has the composition that the re-operation which reasks for the look location except the error which originates in a motion of Operator's M head in quest of movement magnitude deltaP of the pupil center position by motion of a head is performed. Consequently, exact detection by the algorithm of a pupil core method is always performed, and the look location where Operator's M eyeball is exact can always detect, without being influenced by the installation location of the angle of rotation of an eyeball, or the illumination light for an image pick-up.
[0053] This invention is not restricted to the gestalt of the above-mentioned implementation, and can carry out deformation implementation as follows.
[0054] (1) If required location detection is possible, you may make it adopt in the example, the configuration which binary--ization-processes an eyeball image, although it was the configuration of 3-value--ization-processing an eyeball image.
[0055] (2) In the example, although it was the configuration of deciding a look location because there was a blink, the thing of a configuration of deciding a look location by switch actuation or look duration is mentioned as a modification.
[0056] (3) In the case of the example, it was the configuration that the detection result of a look location was used for the alter operation of a computer, but in this invention, the detection result of a look location may be a configuration used for things other than the alter operation of a computer, and may be only a configuration which only searches for the detection result of a look location.

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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is the block diagram showing the whole computer communication system configuration using an example of the look detection equipment of this invention.
[Drawing 2] It is drawing showing an example of the screen for alter operation of the computer of the system of an example.
[Drawing 3] It is drawing showing change of the pupil center position produced in connection with a motion of an operator head in the eyeball image of an example.
[Drawing 4] It is drawing showing other examples of the screen for alter operation of the computer of the system of an example.
[Drawing 5] It is drawing showing other examples of the screen for alter operation of the computer of the system of an example.
[Drawing 6] It is the flow chart which shows the advance situation of communication by the system of an example.
[Description of Notations]
1 -- Optical Image Pick-up Device
2 -- Look Detection Equipment
2D -- Pupil core method operation part
2E -- Cornea reflection method operation part
2F -- Detection result difference judging section
2G -- Head movement magnitude calculation section
3 -- Personal Computer
4 -- Head Mount Display
PA -- Screen for alter operation
PT, Pt -- Look location
M -- Operator

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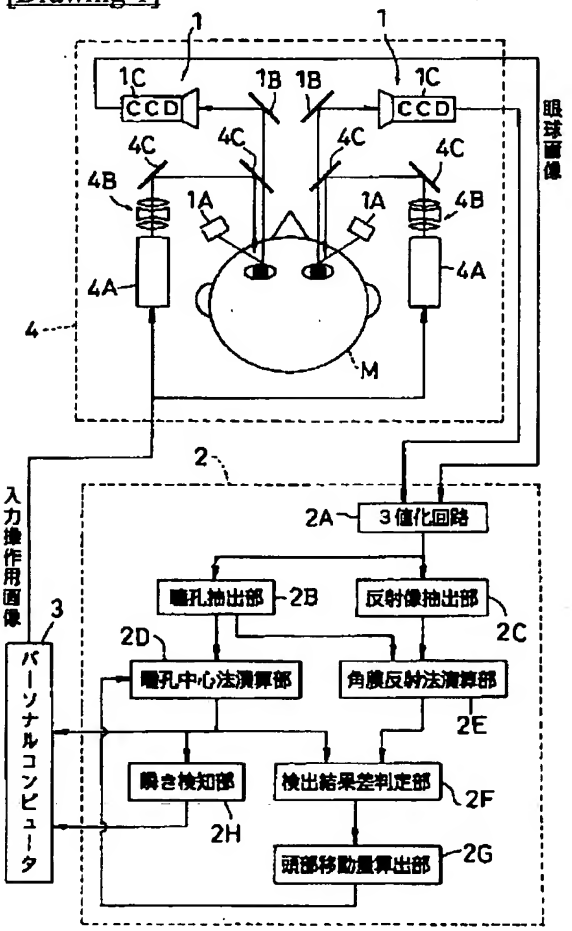
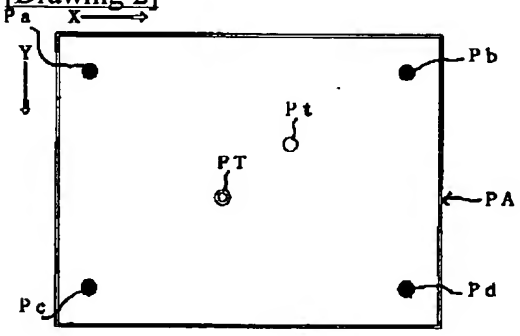
DRAWINGS

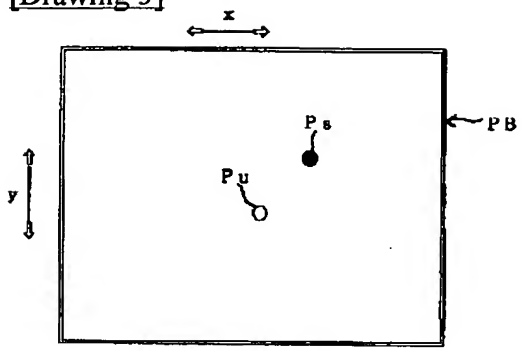
[Drawing 1]



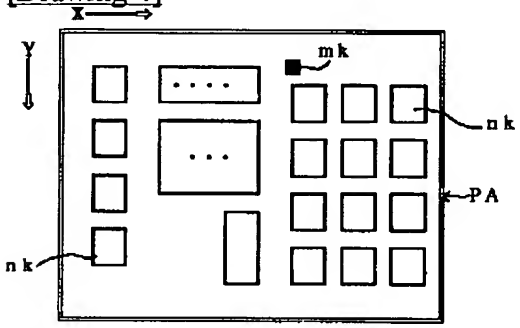
[Drawing 2]



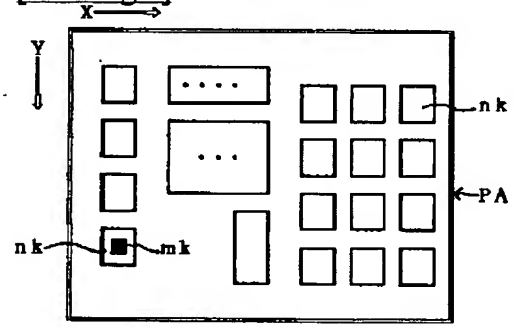
[Drawing 3]



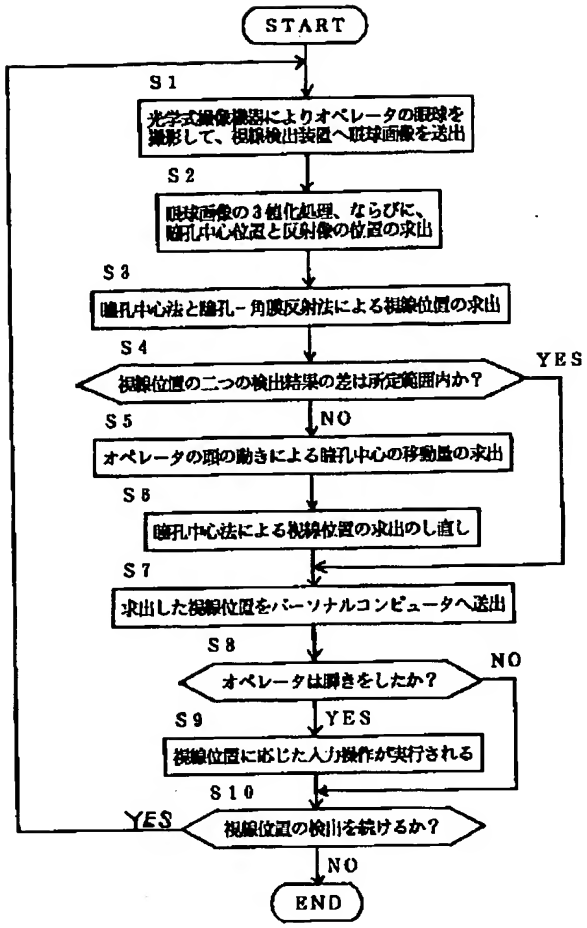
[Drawing 4]



[Drawing 5]



[Drawing 6]



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